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Design for a
Steel Grand-stand

Civil Engineering

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DESIGN

FOR A

STEEL GRAND-STAND

BY

CHARLES E. RAPP

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

PRESENTED JUNE, 1906

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UNIVERSITY OF ILLINOIS

March 10, 1906

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

CHARLES EDWARD RAPP

ENTITLED DESIGN FOR A STEEL GRAND-STAND

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Civil Engineering

Irvin Baker

HEAD OF DEPARTMENT OF Civil Engineering



U N I V E R S I T Y O F I L L I N O I S

March 1, 1906

This is to certify that the thesis prepared under
the immediate direction of Instructor C. W. Malcolm by

CHARLES EDWARD RAPP

entitled DESIGN FOR A STEEL GRAND-STAND

is approved by me as fulfilling this part of the requirements for
the Degree of Bachelor of Science in Civil Engineering.

Ira O. Baker.

Head of Department of Civil Engineering

Introduction.

The object of this thesis is to design a steel grand-stand for Illinois Field, University of Illinois, which shall have a seating capacity between five thousand and five thousand five hundred people. The field is very level and no contour map need be made. Since the "gridiron" is 330 feet long, a stand will be designed for a length of 250 feet. With this length and seating capacity, the grand-stand will be designed so that a portion of the seats are on the roof.

It is only of recent years that steel grand-stands have been under consideration, but at the present time several large driving parks have built, or are contemplating the building of, large steel grand-stands. The first one was erected at Monmouth, New Jersey. It was designed by Mr. F.S. Williamson, and is 700 feet long, 210 feet wide, and will accommodate 10,000 people. It is notable for its size and its cantilever roof, which projects 75 feet to the front and 25 feet to the rear of the main structure. Another grand-stand erected at Yonker's, New York, for the Empire City Trotting Club, has a capacity of 7,700, and was built at a cost of \$100,000. This is 400 feet long, 90.5 feet wide, over all, and 70 feet high. This stand also has a cantilever roof, which projects 20.5 feet to the front and 15.5 feet to the rear. The largest and most costly structure of this type ever constructed is at Belmont Driving park, on Long Island, near New York

City. It is 650 feet long, 116 feet wide, and 55 feet high, and has a seating capacity of 11,000 people. There are 4,500, 000 pounds of steel in the structure, its total cost being \$450, 000.

The Design.

The grand-stand is 250 feet in length, 75 feet in width, and 61 feet 3 inches in height, with a cantilever roof extending 8 feet over the front (See page 10). The seat trusses and the roof trusses are spaced 16 feet 8 inches a part, with columns at each truss in the rear, while along the front they are supported only at every third truss in order to obstruct the view as little as possible. The intermediate roof trusses are supported in front by means of trusses 4 feet deep fastened to the front columns. There are twenty-six rows of seats in the main seating portion, with 5-foot aisles spaced every 50 feet (See page 10). Each aisle will have an entrance from the front of the grand-stand. There are nine rows of seats on the roof with aisles as in the main seating portion (see page 10). The seats on the roof are reached by means of two 4-foot stairways, one at each end of the grand stand (See the side elevation, page 9). The seats are of slag concrete with 2-inch boards fastened to concrete as shown in the detailed drawing (see page 9). The seats in the main portion have backs, while those on the roof have none.

It was decided that a symmetrical Fink truss would be

the best form of roof truss, since the front portion of the roof will be used for seats. This will give a better view of the field to those seated on the roof.

The Specifications.

Ketchum's "General Specifications for Steel-Frame Mill Building" was used in this design. A dead or minimum snow load of ten pounds per square foot, horizontal projection was used. A maximum snow load was taken at 20 pounds per square foot horizontal projection. The wind load was obtained from a curve based on Duchermin's formula, considering the wind force as 30 pounds per square foot, vertical projection. This gave 20 pounds per square foot, normal projection, for each side of the roof, since the roof truss is symmetrical. The roof trusses were designed to take the maximum stress caused by the maximum wind and minimum snow, acting together; or by the dead load and maximum snow load acting together. It is not necessary to consider the maximum snow and the maximum wind acting together, as this condition will never exist. The wind load on the seats was taken as 20 pounds per square foot, vertical projection.

The allowable unit tensile stress was taken as 16,000 pounds per square inch of net section. The allowable unit compressive stress used was :

$$16,000 - \frac{1}{70r} ,$$

where $\frac{1}{70r}$ = length of member in inches, center to center of end connections,

\underline{r} = least radius of gyration of member in inches.

The allowable shearing stress on the rivets was taken as 11,000 pounds per square inch, and the bearing value as 22,000 pounds per square inch. Field riveting was considered to be two-thirds as efficient as shop riveting, and was avoided where possible .

Slag concrete was used for the steps, (see page 9), instead of crushed stone concrete, to reduce the weight of the structure as much as possible; and its weight was taken as 100 pounds per cubic foot. The dead load of the seats, including concrete, angles, plates, corrugated steel, lumber, etc., was taken as 33 pounds per square foot. The live load, considering the weight of the average person as 150 pounds, is 38 pounds per square foot. The total load as calculated equals 71 pounds per square foot. The seats and seat trusses were designed for a total load of 75 pounds per square foot.

Since the roof trusses are fixed in the rear by the seat trusses, (See page 9), there is no bending moment in the front post. The cantilever roof projects 8 feet in front of the main roof to protect the persons in the front rows of seats from inclement weather.

The symmetrical type of roof truss gave the persons seated on the roof the best possible view of the field. In selecting the type of the roof due consideration was given to the view of both the people in the main seating portion and also on the roof. There are nine rows of seats on the roof.

(see page 9) . If more than this number be used, the people occupying the top seats will be annoyed by the wind blowing upon them from the rear of the grand-stand.

The seats on the roof are reached by means of a stairway fourfeet wide at each end of the grand-stand (see page 10). The stairway has two intermediate platforms , 4x5 feet, and a top platform, 4x4 feet (see page 10). Between the platforms are nineteen steps, 1 foot wide, and nine inches high. Each platform is supported by four columns composed of 4"x4"x 5/16" angles, which also carry the step construction (See page 9). These columns are braced every 7 feet 6 inches with 2"x2"x1x4" angles. These steps are carried by three rows of 10 -inch 15-pound channels. On these channels are bolted special cast-iron stair sections. The steps are made of a checkered cast-iron plate 1'x1/4"x4'. The platforms are of concrete construction same as the seats and supported by channels connected to the columns.

As there is a great tendency for the wind to overturn a structure of this kind, especially when there are no people in it , large footings must be used . The largest of these are under the front intermediate seat trusses . When the wind acts from the front, these footings are subjected to a large sliding and overturning force acting towards the rear. The footings are designed to resist this force, which accounts for their form and size (see page 9).

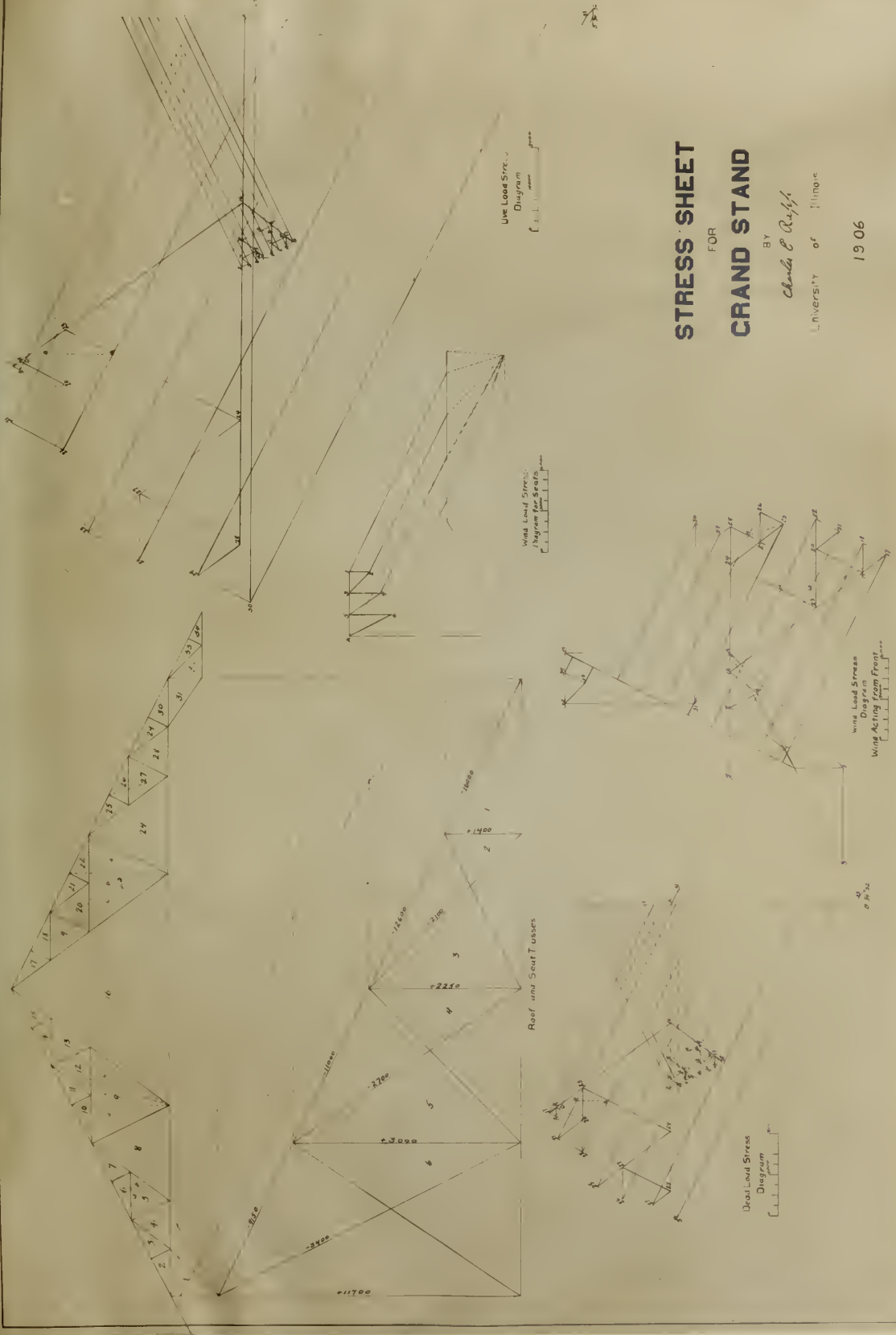
Stress Diagrams.

The stresses in the roof truss and other parts of the structure for the various loads and the different combinations of them are shown in the diagrams on pages 7 and 8. The maximum stresses are shown on page 8.

Weight and Cost.

The weight of the metal in the grand-stand, exclusive of the corrugated steel and gas pipe, is 445,910 pounds. The structure contains 189, 280 pounds of galvanized corrugated steel, 2,350 feet of gas pipe, 315 cubic yards of concrete, and 33,110 feet of lumber.

In estimating the cost of the grand-stand the following prices were used: structural steel placed and painted, 3 3/4cents per pound; galvanized corrugated steel placed , 3 cents per pound; concrete placed, \$6 per cubic yard; lumber, \$27 per thousand feet; gas pipe, 8 1/2 cents per foot. With these prices the total cost of the grand-stand is \$25,400.



STRESS SHEET
FOR
GRAND STAND

BY

Charles E. Rapp

University of Illinois

1906

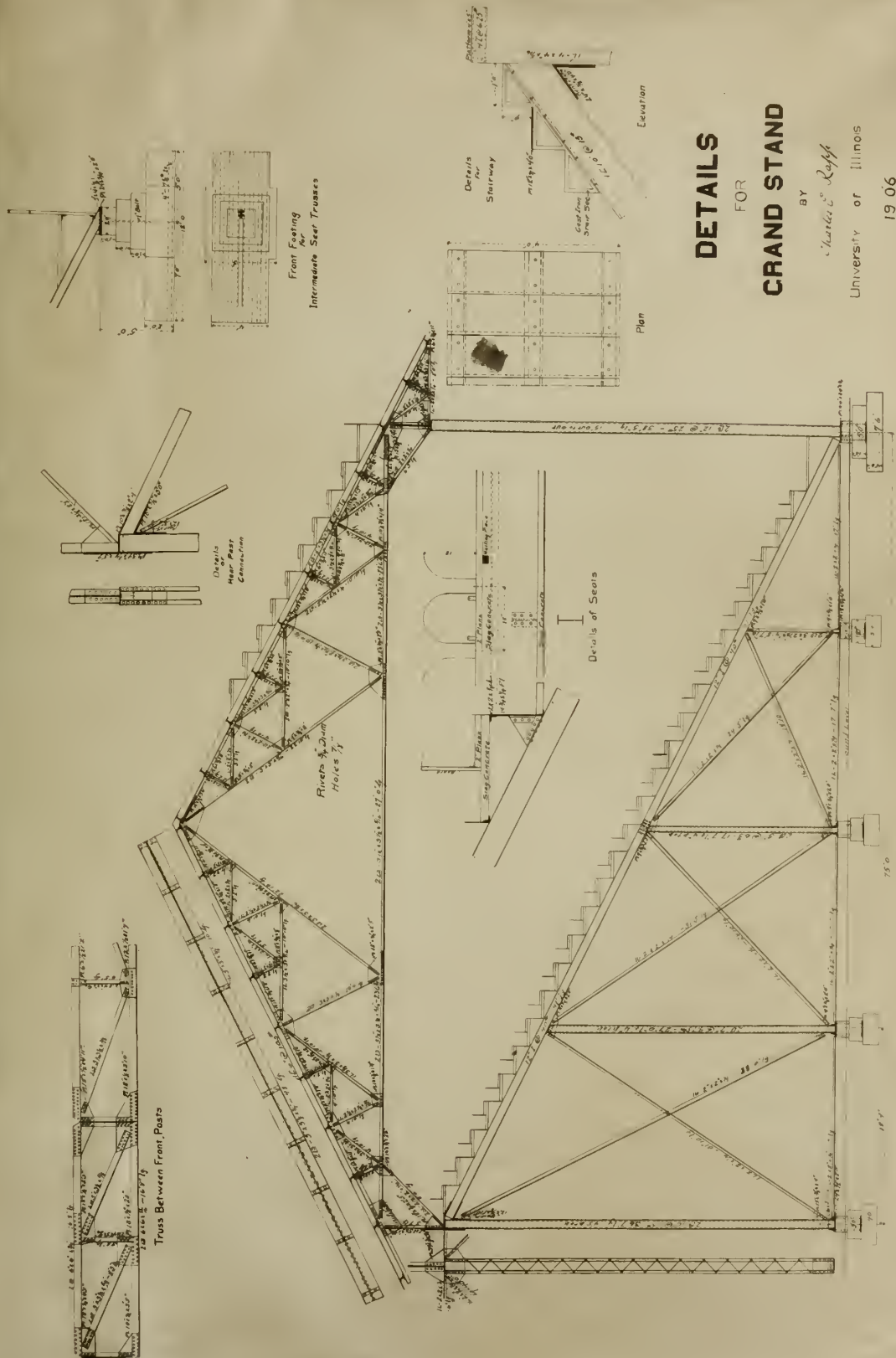
Truss Between Front Posts

Wind Load Stress
Diagram
Wind Acting from Front

STRESS SHEET FOR CRAND STAND

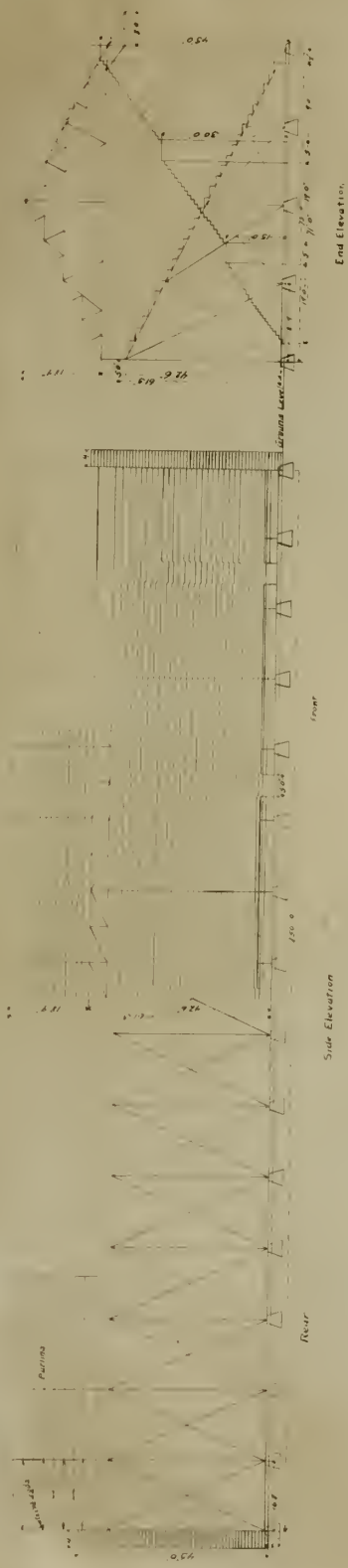
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DETAILS
FOR
GRAND STAND

BY
C. H. Rapp
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1906



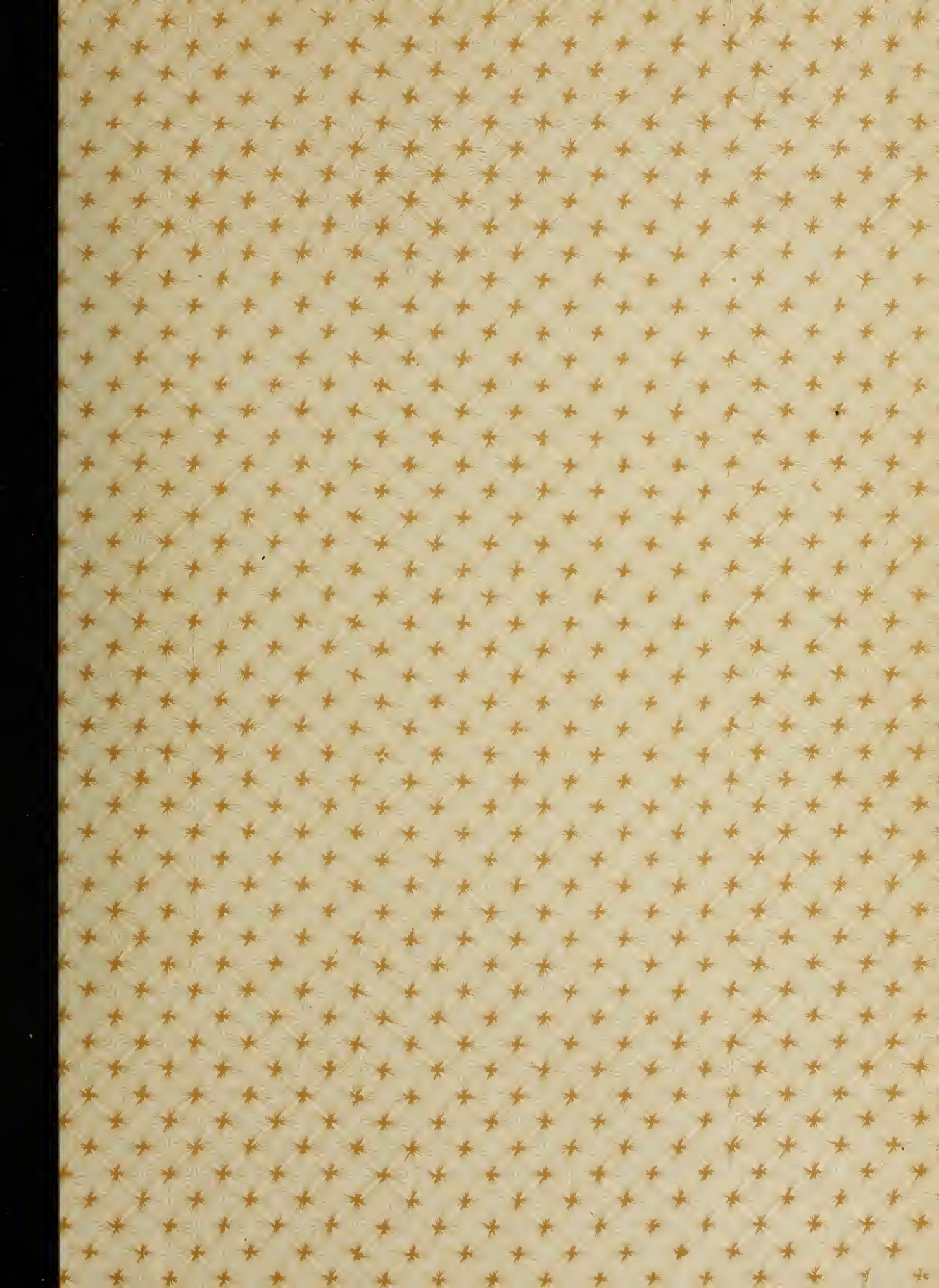
GENERAL PLAN & ELEVATION FOR GRAND STAND

BY
Charles C. Taylor
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